Multi-Step Energy Calculations, Extra Exercises

1. For the following combustion, what mass of carbon dioxide is produced when 1500 kJ of energy is released?

   $2\ C_2H_{6(g)} + 7\ O_{2(g)} \rightarrow 4\ CO_{2(g)} + 6\ H_2O_{(g)} + 2502\ kJ$

2. How much energy is released when 1.00 t of sulfur trioxide is produced by the following reaction?

   $2\ SO_{2(g)} + O_{2(g)} \rightarrow 2\ SO_{3(g)}$ $\Delta H = -192.8\ kJ$

3. In respiration, glucose is oxidized by oxygen gas to produce carbon dioxide gas, liquid water, and energy. What is the energy released when 18.0 g of glucose is consumed?

4. Methanol is burned in a bomb calorimeter. Liquid water is formed as a product. If 3.40 g of methanol reacts, what is the expected temperature change in a calorimeter with a heat capacity of 6.75 kJ/°C?

5. A waste heat exchanger is used to absorb the energy from the complete combustion of hydrogen sulfide gas. What volume of water undergoing a temperature change of 64°C is required to absorb all of the energy from the burning of 15 kg of hydrogen sulfide?

Multi-Step Energy Calculations, Extra Exercises, Solution

1. For the following combustion, what mass of carbon dioxide is produced when 1500 kJ of energy is released?

$2\ C_2H_{6(g)} + 7\ O_{2(g)} \rightarrow 4\ CO_{2(g)} + 6\ H_2O_{(g)} + 2502\text{ kJ}$

$$\Delta H_c = \frac{\Delta H}{n} = \frac{-2502\text{ kJ}}{4\text{ mol}} = -626\text{ kJ/mol } CO_2$$

$$\Delta H = n\Delta H_c$$

$$1500\text{ kJ} = m \times \frac{1\text{ mol}}{44.01\text{ g}} \times 626\text{ kJ/mol}$$

$$m = 106\text{ g}$$

2. How much energy is released when 1.00 t of sulfur trioxide is produced by the following reaction?

$2\ SO_{2(g)} + O_{2(g)} \rightarrow 2\ SO_{3(g)}$ $\Delta H = -192.8\text{ kJ}$

$$\Delta H_r = \frac{\Delta H}{n} = \frac{-192.8\text{ kJ}}{2\text{ mol}} = -96.4\text{ kJ/mol } SO_3$$

$$\Delta H = n\Delta H_c$$

$$= 1.00\text{ Mg} \times \frac{1\text{ mol}}{80.06\text{ g}} \times \frac{96.4\text{ kJ}}{1\text{ mol}} = 1.20\text{ GJ}$$

3. In respiration, glucose is oxidized by oxygen gas to produce carbon dioxide gas, liquid water, and energy. What is the energy released when 18.0 g of glucose is consumed?

$$C_6H_{12}O_{6(s)} + 6\ O_{2(g)} \rightarrow 6\ CO_{2(g)} + 6\ H_2O_{(l)}$$

$$\Delta H = \sum nH^\circ_{f(\text{products})} - \sum nH^\circ_{f(\text{reactants})}$$

$$= \left(6\text{ mol} \times \frac{-393.5\text{ kJ}}{1\text{ mol}} + 6\text{ mol} \times \frac{-285.8\text{ kJ}}{1\text{ mol}}\right) -$$

$$\left(1\text{ mol} \times \frac{-1273.1\text{ kJ}}{1\text{ mol}} + 6\text{ mol} \times \frac{0\text{ kJ}}{1\text{ mol}}\right) = -2802.7\text{ kJ}$$

$$H_c = \frac{-2802.7\text{ kJ}}{1\text{ mol}} = -2802.7\text{ kJ/mol } C_6H_{12}O_6$$

$$\Delta H = n\Delta H_c$$

$$= 18.0\text{ g} \times \frac{1\text{ mol}}{180.18\text{ g}} \times \frac{2802.7\text{ kJ}}{1\text{ mol}} = 280\text{ kJ}$$

(continued)

4. Methanol is burned in a bomb calorimeter. Liquid water is formed as a product. If 3.40 g of methanol reacts, what is the expected temperature change in a calorimeter with a heat capacity of 6.75 kJ/°C?

$$CH_3OH_{(l)} + \frac{3}{2}O_{2(g)} \rightarrow CO_{2(g)} + 2\,H_2O_{(l)}$$

$$\Delta H = \sum nH^{\circ}_{f(products)} - \sum nH^{\circ}_{f(reactants)}$$

$$= \left(1\text{ mol} \times \frac{-393.5\text{ kJ}}{1\text{ mol}} + 2\text{ mol} \times \frac{-285.8\text{ kJ}}{1\text{ mol}}\right) - \left(1\text{ mol} \times \frac{-239.1\text{ kJ}}{1\text{ mol}} + \frac{3}{2}\text{ mol} \times \frac{0\text{ kJ}}{1\text{ mol}}\right) = -726.0\text{ kJ}$$

$$\Delta H_c = \frac{726.0\text{ kJ}}{1\text{ mol}} = -726.0\text{ kJ/mol } CH_3OH$$

$$\underset{\text{(methanol)}}{\Delta H_c} = \underset{\text{(calorimeter)}}{C\Delta t}$$

$$3.40\text{ g} \times \frac{1\text{ mol}}{32.05\text{ g}} \times \frac{726.0\text{ kJ}}{1\text{ mol}} = \frac{6.75\text{ kJ}}{°C} \times \Delta t$$

$$\Delta t = 11.4°C$$

5. A waste heat exchanger is used to absorb the energy from the complete combustion of hydrogen sulfide gas. What volume of water undergoing a temperature change of 64°C is required to absorb all of the energy from the burning of 15 kg of hydrogen sulfide?

$$H_2S_{(g)} + \frac{3}{2}O_{2(g)} \rightarrow SO_{2(g)} + H_2O_{(g)}$$

$$\Delta H = \sum nH^{\circ}_{f(products)} - \sum nH^{\circ}_{f(reactants)}$$

$$= \left(1\text{ mol} \times \frac{-296.8\text{ kJ}}{1\text{ mol}} + 1\text{ mol} \times \frac{-241.8\text{ kJ}}{1\text{ mol}}\right) - \left(1\text{ mol} \times \frac{-20.6\text{ kJ}}{1\text{ mol}} + \frac{3}{2}\text{ mol} \times \frac{0\text{ kJ}}{1\text{ mol}}\right) = -518.0\text{ kJ}$$

$$\Delta H_c = \frac{-518.0\text{ kJ}}{1\text{ mol}} = \frac{-518.0\text{ kJ}}{\text{mol}}\,H_2S$$

$$\underset{H_2S}{\Delta H} = \underset{\text{(water)}}{q}$$

$$n\Delta H_c = mc\Delta t$$

$$15\text{ kg} \times \frac{1\text{ mol}}{34.08\text{ g}} \times \frac{518.0\text{ kJ}}{1\text{ mol}} = m \times 4.19\,\frac{\text{kJ}}{\text{g•°C}} \times 64°C$$

$$m = 850\text{ g}$$

$$v = 0.85\text{ L}$$